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Concept Design & Validation of Digger cum Winch attachment for Skid Steer Single Arm Product

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ABSTRACT

This paper focuses on concept design of Digger cum Winch attachment for SKID STEER machine to reduce project execution time of highways. Today's market requirement for construction equipment is changed, customer wants to save time as well as money during execution of project by using single machine which will perform multiple tasks. Customers not only avoid use of multiple machines for different applications but also want to save tool or attachment changing time for the same machine. This urge comes in to mind because of huge development & investment in highway constructions to enhance good transportation. This brings idea of digger cum winch attachment which will serve different application like trenching, able to grounding of high extension cables as well as pipe installation across the road side. This is multipurpose attachment, which can be used for trench, remove stumps, transplant trees, as well as loosen hard packed soil. SKID STEER machine which effectively perform multiple task by simply changing the attachments within short interval of time is good for bench marking the concept design. The methodology adopted is to find maximum digging force for the given cylinder pressure and this is done using parametric design. The second stage is to find the forces at all pivot points of the attachment, this is done using MathCAD. Digger cutter plate is made from structural steel of grade EN10025-S355 while the child parts are made from EN10025-S275 to sustain long durability. Concept validation will be through Finite Element Analysis (FEA) & Endurance Test.

Keywords- **Breakout Force, Concept Design, FEA, Proto Build, Skid Steer machine**

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I. INTRODUCTION

Today's market requirement is quite different & customer needs are also changing which gives us opportunities to launch new segment of products which can deliver or fulfill the market needs. Digger cum winch attachment case falls into such one of the requirement which comes under agriculture and highway construction to make small trenches. Digger is useful for making trenches, grounding of high extension cable in highly dense areas, canalling, optical fibre cable installation; it is also used to loosen hard packed soil. Digger attachment can be used on skid steer machine because it consumes less space & preferably can also be use in highly dense areas. This attachment use different tools for different application. For effective utilization digger is designed in such way that it can use its both forward & backward sides for line up the trenches i.e. dual cutting edge both front & back. Digger cutter plate is made from structural steel of grade EN10025-S355 while the child parts are made from EN10025-S275 to sustain long durability.

I. CONCEPT FORMULATION

It is very difficult to make trenches at critical road site work as well as time consuming in highway construction which lags actual project time. Even due to unavailability of workers and attachment replacing time for same construction equipment delay the project execution work. Grounding of high extension cable, communication optical fibre cables, cannels for irrigation required small trenches & urban area piping to supply water for societies also hamper.

Before starting with problem statement it is very curious to ask 'What are the today's methods of digging the trenches?' Maybe there are a few methods, but are they feasible or valid with time constrains. Current methods which are using now are critical and time consuming, so can we make concept for this issue which can reduce efforts, time, able to do multiple task & especially cost effective one. So these problems originate a concept of digger which not only solve such issue but also effectively utilized for different application for respective fields [2].

II. Research Work

Digger attachment for Skid Steer is designed for multipurpose applications based on customer's needs. Digger child parts design for maximum breakout force. Work started with static analysis of a mechanism with given input conditions of hydraulic cylinder. Thus with this final breakout force and tractive force are calculated. Next CAD model of each child part is modelled in Uni-graphics 8.5 based on application and is then assembled. Parametric assembly of the mechanism is done for the purpose of understanding the feasibility of a mechanism and analyzing the behavior of mechanism by varying input conditions.

III. Concept Modeling

A model is a representation or idealization of the structure, behaviour, operation, or other characteristics of a real-world system. A model is used to convey the design information, simulate real world behaviour, or specify a process. Engineers use models to convey product definition or otherwise define a product's form, fit and function.

Before designing of digger cum winch attachment - Skid Steer Arm, Tilt Ram & Quick Hitch is carefully understand how they are working together at pivots points. Considering locking pins of quick hitch as a bench marking point for back plate design because this locking pin work as a grabber for digger attachment. For design of back plate care should be taken for angles & faces of back plate are matched with face of quick hitch. This gives the idea about benchmarking principle of any product development process.

Side plate are responsible to give path and shape to make proper trenches size, while stiffening rib are give the backing support to overall structure. One of the important components which avoid bending movement in both LH & RH side plate is C-channel & hallow tube (torsion). This will give additional strength to structure.

Cutter blade is a critical component of digger because it has to sustain both tilt ram & tractive forces. Digger cutter's shape is made in such way that it can utilize both edges so that trenches are made easily with less time. Winch is additional hand to this digger attachment for lifting cable rolls & pipes or may be rods on construction site [6] [7].

Figure 1 SKID STEER machine with digger attachment

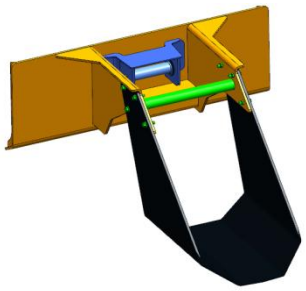

Figure 2 Isometric view of digger cum winch attachment

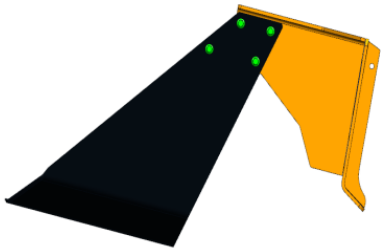

Figure 3 Side view of digger cum winch attachment

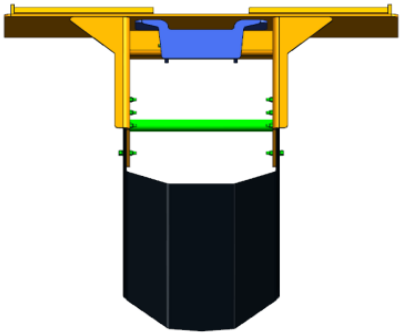

Figure 4 Top view of digger cum winch attachment

IV. Material & Weld Design

Materials are the key factor in construction equipment manufacturing because due to high fatigue wear & tear of components occurs in rough territories such as mining industries, construction & agriculture. Digger attachment need's material which have more yield value but it signifies more will be the cost of material, so considering aspect of optimization we can reduce it by selection of different material considering the load cases which occur in FEA. We identify three materials which are mostly used in construction equipment manufacturing industries for such application as follows- EN10025-S275, EN10025-S355 & HARDOX 400. Weld detailing is done based on standard BS7608 for better weld fatigue life.

V. Parametric Design

In parametric design the attributes of component identified in configuration design become the design variable for parametric design. The objective of parametric design is to set values for design variables that will produce the best possible design considering both performance and cost.

Systematic steps in parametric design

- ✓ Formulate the parametric design problem
- ✓ Generate alternative design
- ✓ Analyze the alternate design
- ✓ Evaluate the results of the analyses
- ✓ Refine or Optimize

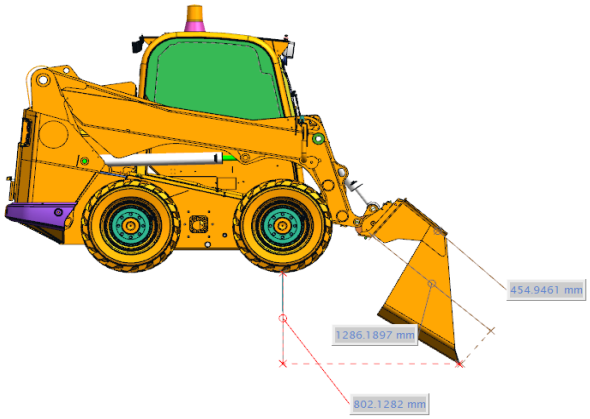

Figure 5 Parametric Model

VI. Force/Kinematic Calculations

To find the forces at different points of the attachment is very important as it plays a crucial role in the analysis, for getting results close to the actual it is required to have accurate values of forces at all pivot points. The methodology adopted is to find a maximum digging force for the given cylinder pressure, and this is done using design view. The second stage is to find the forces at all pivot points of the attachment, this is done using MathCAD.

Tilt Ram Force Calculation –

1. System Pressure = 230 bar = 23 N/mm2
2. Cylinder Bore ID (D) = 100mm
3. Cylinder Rod OD (d) = 50mm
4. Closed Length – 632mm
5. Stroke Length – 333mm

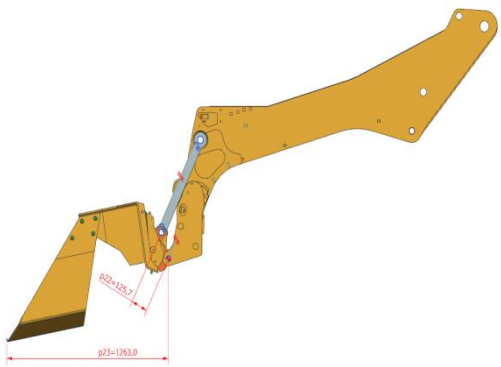

Figure 6 Pivot Point Distance

Case1. Under the Application Ram Force

A) Ram Extension Force

$$\text{Area} = A = \frac{\pi}{4} * D^2$$

A = 0.785 * 1002
A = 7850mm2
$F = P * A$
F = 23 * 7850
= 180550 N
Now,
F1*S1 = F2*S2
F2 = (F1*S1)/S2
F2 = 180550 * 127.5 / 1263
F2 = 18226 N
F2 = 1822 Kg.

B) Ram Contraction Force

$$\text{Area} = \frac{\pi}{4} * (D^2 - d^2)$$

A = 0.785 * (1002 - 502)
A = 5887.5 mm2

$F = P * A$
F = 23 * 5887.5
= 135412.5 N
Now,
F1*S1 = F2*S2
F2 =(F1*S1)/S2
F2 = 135412.5 * 127.5 / 1263
F2 = 13669 N
F2 = 1366 Kg.

Case2. Under the Application Tractive Force

Tractive force for Skid Steer 155 Model: 90% of its operating weight

T = 2844*90/100
T= 2559.6 Kg

VII. FINITE ELEMENT ANALYSIS

Finite Element Analysis (FEA) is the most powerful technique in strength calculations of the structures working under known load and boundary conditions. In general, computer aided drawing (CAD) model of the parts to be analyzed must be prepared prior to the FEA. Product development times and costs have been reduced as a result of using the CAD software.

Preparation of the CAD model can be done either using a commercial FEA program or using a separate commercial program, which is specialized for CAD. Structural optimization for strength is a popular subject in modern engineering design. It has been widely used to obtain an optimum strength/material mass ratio for structures under specified load conditions [7].

Finite element analysis is an important part of the overall design process, serving to verify or validate a design prior to its manufacture. Because finite element analysis is a simulation tool, the actual design is idealized, with the quality of the idealization dependent on the skill and experience of the analyst.

Accuracy of results is dependent on choice of elements, number of nodes, selection of proper material, boundary conditions, applied loads and expertise of the analyst. Principal steps of Finite Element Analysis are Creation of geometry and its cleanup, specify material and element properties, meshing of geometry in into nodes and elements, apply the loads and boundary conditions, and finally carry out the solution and post processing results. After getting the results, interprets the results and do required corrective steps on it to fulfill the requirement of the problem [4][5].

CAD model is constructed in Unigraphics NX 8.5; it is then imported in ANSYS Workbench 14.5 for structural analysis of wheel loader.

Steps followed for FEA of Digger cum Winch attachment are:

A. Pre-processing

1. Define CAD model
2. Define local coordinate system to define boundary conditions.
3. Define contacts in parts of CAD assembly.
4. Mesh CAD model.
5. Apply loads and boundary condition.

B. Solution

C. Calculate the unknown values such as support reactions, element stress, displacement etc.

D. Post processing

E. It consists of sorting, printing and plotting results from solution obtained.

VIII. CONCLUSION

To find the forces at different points of the attachment is very important as it plays a crucial role in the analysis, for getting results close to the actual it is required to have accurate values of forces at all pivot points. The methodology adopted is to find maximum digging force for the given cylinder pressure, and this is done using design view. The second stage is to find the forces at all pivot points of the attachment, this is done using MathCAD.

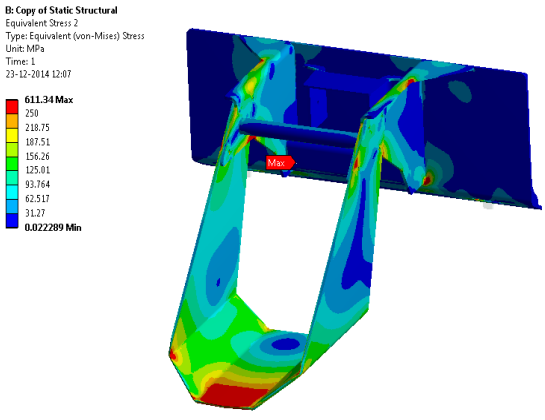

Figure 7 Von Misses Stresses of Digger

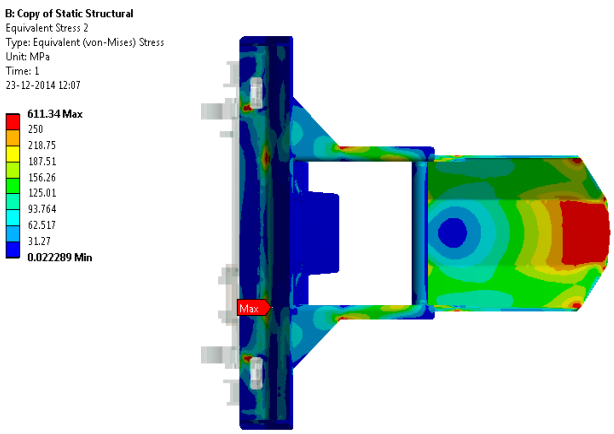

Figure 8 Von Misses Stresses of Digger

Finite Element Analysis (FEA) is the most powerful technique in strength calculations of the structures working under known load and boundary conditions. To carry out the modeling and finite element analysis for digger Unigraphics 8.5 & ANSYS software's are used. By conducting FEA it is very easy to identify weak areas or components through strength analysis of digger attachment and implement correction in early stage of design.

The digger design Concept behaves well under considerable worst loading with using FEA tool. Small hot spots can be eliminated by smoothing profile & blend radius change.

In future optimization techniques will be used to improve digger concept with implementation of modification to enhance robust design for manufacturing.

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